GLOSTEN
The Glosten Associates, Incorporated

600 Mutual Life Building
605 First Avenue
Seattle, Washington 98104-2224

Fax: 206-682-9117
Phone: 206-624-7850
E-mail: email@glosten.com

# MEMORANDUM

**Ballast Dispersion Study**
**Summary of Presentation to Washington State Environmental Soundness Work Group**

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| From: | Kevin Reynolds |
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Kevin Reynolds, of The Glosten Associates, presented the attached presentation, *Ballast Dispersion Testing*, to the Washington State Environmental Soundness Work Group on 8 January 2004. The following provides introductory information, a description of the verbal portion of the presentation, and discussion of the questions and answers which followed the presentation.

## INTRODUCTORY INFORMATION:

Understanding ballast water dispersion is fundamental to stemming the tide of non-indigenous species. This understanding is key to performing environmental impact analyses on vessel discharges of biocide treated or otherwise altered ballast water discharges.

Recognizing the need for developing this understanding, and with the encouragement from the Washington State Aquatic Nuisance Species Coordinator, The Glosten Associates proposed a full scale ballast water dispersion study to the Environmental Protection Agency in December 2002. Having not received funding from EPA, The Glosten Associates started work on this project with funds directly from Vitamar, agents for SeaKleen, in October 2003. This first trial will be performed on a vessel which supports the needs of SeaKleen. The results of this work will be published into the public domain to support additional needed work.

## PRESENTATION SUMMARY:

### Introduction

An overview of the ballast dispersion testing objectives and methods was presented to the work group for their comment. Comments will be incorporated into the protocol planned for submission to the Washington State Department of Ecology.

It is the objective of this testing to determine the dispersion characteristics of a ballast water discharge plume from a specific vessel under specific conditions, defining a baseline. This baseline will provide (1) a tool for determining the dilution of ballast water as it leaves the vessel, (2) a guide for determining additional testing and analysis needs. It is important to note that this testing considers near field, within 50 feet of the overboard, dispersion. This requires considerations significantly different than most hydrological studies which consider greater distances.

## Glosten

The Glosten Associates are marine engineers, naval architects and ocean engineers. Additional information on Glosten can be found at www.glosten.com.

## Ballast Systems

Ballast systems come in significantly different capacities and pumping rates. Consider a crude oil tanker at 60,700 tons capacity and 2,860 tons per hour pumping rate. Consider a car carrier at 6,400 tons capacity and 350 tons per hour pumping capacity. Ballast is generally loaded as cargo is discharged to:

- Control hull stresses
- Ensure vessel stability – resistance against capsize
- Submerge propeller
- Reduce slamming of waves impacting the hull

Ballast systems are integral with the safe operation of the vessel, and are comprised of complex machinery.

## Review of the Variables in Ballast Water Dispersion

The ballast water dispersion testing will be conducted on board a working merchant vessel, through dosing a ballast tank with rhodamine WT, and then monitoring the discharge of this dosed tank within 50 feet of the vessel overboard. This test will be:

- Conducted at a 'worst case scenario'
- Provide a dispersion ratio order of magnitude for this specific vessel
- Define a baseline of specific variables, to support further testing and analysis

The sampling method involving use of a dingy near the ballast overboard is discussed in the testing procedure section.

The variables listed below will be monitored. A 'worst case scenario' will be created to the extent possible to limit dilution of the ballast water, while maintaining the integrity of this baseline data for further testing and analysis.

### Discharge Kinetics

- The relative density of the ballast water to the **sea** (body of water the ballast is discharged into) influences the tendency of the plume to rise or fall, and maintain itself as a cohesive body. This relationship is affected by temperature, specific gravity (salinity) of the water. The testing will be performed in neutrally buoyant conditions, by means of loading the ballast into the vessel from the sea just prior to conducting test.
- Volume flow rate and discharge velocity influence the mixing of the ballast with the sea, as well as the distance from the hull of this mixing effect. These two variables work together and are interdependent. The testing will be performed on a vessel which discharges from its seachest, which offers very low discharge velocities, encouraging minimal mixing with the sea.

**Environmental Conditions**

- Current speed and direction can influence a plume by elongation in the direction of the current. Testing conditions will be difficult to control given vessel availability. Current less than 1 knot and light wind conditions will be targeted.
- Wind/wave force and direction can disperse a plume which reaches the surface of the sea. Testing conditions will be difficult to control given vessel availability. Calm conditions will be targeted.
- Vessel relative heading will influence plume shape if allowed to interfere with the vessel hull. It is possible that wind and a large vessel sail area, could push a vessel broadly against a light current. In this case the plume could be driven against the vessel hull. Testing conditions will seek to avoid this, allowing proper measurement of the plume.

**Vessel and Load Configuration**

- Overboard configuration and orientation can influence the direction of the plume, and determine the discharge kinetics. The direction of the plume may cause impact with the waterway. The test vessel has a seachest configuration at the bilge turn, which provides a very low discharge velocity, horizontal or downward discharge direction.
- Vessel draft at discharge will effect whether the discharge is above the waterline, or whether the plume will reach the surface of the sea.

**Waterway Geometry**

- Depth and width of the waterway and obstructions may be impacted by the plume, causing changes to the dispersion. A narrow width may cause the plume to concentrate if it recalculates back towards the overboard. A piling in the plume path could break-up the plume. To define the baseline variables, the testing will be conducted in a location with minimal waterway influences.
- Tidal conditions can recalculate a plume back to the overboard location. In this way the dilution of the discharge is decreased as the sea already has a significant ballast water concentration. To define the baseline variables, the testing will be conducted in a location where tidal conditions are not significant.

## Testing Procedures

The ballast water dispersion testing will be conducted on board a working merchant vessel, through dosing a ballast tank with rhodamine WT, and then monitoring the discharge of this dosed tank within 50 feet of the vessel overboard.

In conducting this testing, the following is considered:

**Testing Guidelines**

- United States Geological Survey *Flurometric Procedures for Dye Tracing* provides fundamental guidance in handling, dosing, and evaluating results of the dye study.

- Vessel Master will provide guidelines for safe operation on board the vessel. These are considered under the Hazard/Safety Considerations.
- Previous Shipboard Dye Testing Work has resulted in advanced understanding of how vessel systems interact with dye injection and handling.
- Familiarity with Vessel Systems is critical to execution of this work. The experience of the testing team from Glosten, including licensed merchant mariners, will assist in proper evaluation of the system, and safe execution of the protocol. This familiarity will also assist in communications with the vessel crew, ensuring vessel safety requirements are followed.

**Hazard/Safety Considerations**

General hazard/safety requirements are detailed by the Master upon boarding. The can include hazardous zones, personal safety gear, communications methods.

Environmental hazards are to be minimized through following the vessel's procedures for handling the dye, and the instructions on the material safety data sheet. The use of the dye should follow the test protocol such that Washington State Law, RC 90.48 is adhered to. This law requires that no pollutant is discharged into the waters of Washington State.

Operations must be approved by the Master in way of vessel stability, vessel hull stresses, and proper operation of the vessel equipment.

**Rhodamine WT**

The material safety data sheet provides information for the proper handling of the dye. Several published materials detailing the nature of rhodamine WT were reviewed. These include:

- Intracid Rhodamine WT MSDS: This is the MSDS sheet for the actual dye used in the testing. The max concentration of dye to be discharged is 220 ug/L (parts per billion). The MSDS lists "no developmental abnormalities or toxicity to oyster larvae at 100 mg/L," 455 time the maximum concentration for this dispersion testing.
- Intracid Rhodamine WT Spec: This document details common uses including a statement: "Intracid Rhodamine WT Liquid is certified by the National Sanitation Foundation International (NSF International) for use under NSF Standard Number 60, Drinking Water Treatment Chemicals -Health Effects, to trace drinking water."
- Keystone 65 Spec and 89 Spec: The 65 Spec documents that up to 40 parts per million of rhodamine WT are typically used in tracer studies, 181 times the maximum concentration for this dispersion testing. The 89 Spec is more specific to rhodamine WT, and provides additional references regarding environmental hazards.

**Measurement**

Instrumentation of the discharge is to be made with YSI Incorporated instruments. A 650 multiparameter display system logger is used to drive the 600 optical monitoring system sonde. The sonde is outfitted with conductivity, temperature and rhodamine

WT probes. This is attached to a 75 foot extension cable. The logger is waterproof, rated to IP-67. The sonde is suitable for depths to 200 feet.

The sonde provides a range of 0 – 200 parts per billion (ug/L) of rhodamine. It has an accuracy of +/-5% of reading, or +/-1 ug/L which ever is greater. It has a resolution of 0.1 ug/L. Accuracy of testing should be considered in absolute and relative terms.

- Absolute accuracy. Absolute accuracy considers the ability of the instrument to determine the actual concentration of the dye in the ballast water. Considering an initial concentration of 160 ug/L dosed in the ballast tank, we are targeting dilution to 5% initial concentration. Given a reading of 8 ug/L at this concentration, our accuracy would be between 7 and 9 ug/L, or 4 to 6% initial concentration.
- Relative accuracy. Relative accuracy considers the ability of the instrument to compare a reading to one previous. Given a resolution of 0.1 ug/L, the instrument provides the ability to portray a sharp plume image.

**Dye Injection**

Dosing of the tanks is achieved by metering in dye while an empty pair of tanks are being filled. This may be conducted at any time before the discharge monitoring event. This pair need not be completely filled, provided that there is at least two hours of discharge available. The following outlines this process:

- Set-up (90 minutes): Place four equipment pallets on board. Connect dye feed tank, suction and discharge manifolds, discharge connection to ballast system. Make electrical connection. Discuss plan with vessel operators.
- Dose tank pair (depends on system, estimate 3 hours): Tank pair is to be filled as per standard vessel practice, allowing only the filling of this tank pair. No other tanks may be filled at this time. It is acceptable to stop filling this tank pair, perform other ballast operations, then resume filling tank pair. While the tank pair is being filled, the dosing system will meter dye into the ballast main on a continuous basis, specifically matching the ballasting rate. Tank pair only need be filled enough to allow a minimum of two hours of discharge.
- Verify dye concentration/dosing system breakdown (90 minutes): These two operations will take place at the same time. Once the tank pair is full with dyed ballast water, they need to be sampled with the electrical testing gear through the ballast tank accesses. Four equipment pallets to be taken off board.

**Discharge Measurement**

Discharge measurement is the process of measuring dye concentrations in the sea, as ballast water is discharged overboard. At the overboard, a three person team in a dingy will trace a radial pattern measuring dye concentrations in the sea. On board the vessel, a single team member will provide communications with the dingy. The following outlines this process:

- Set-up (performed during dosing tanks event – 60 minutes): Measurement of start event current and wind. Coordination of placing team member aboard, and establishing vessel communications. Place magnets on vessel hull for measurement of radial tracing pattern. Mark hull in way of overboard, and 50 feet forward and aft with non-permanent paint or chalk. Coordinate discharge event start.

- Discharge sampling (depends on system, minimum 2 hours, estimate 3 hours): While vessel is discharging, team will use a line attached to vessel by means of a magnet to trace a radial pattern around the vessel ballast overboard.
  - Setting of the plume will be verified by standing the dingy at 50 feet from the overboard and keeping the probe at the height of the discharge. When the concentration of dye appears to peak, with no appreciable rise, the plume will be considered set.
  - The first sweep at 50 feet will be made by performing a single vertical profile directly outboard of the discharge. Adjacency to the overboard will be confirmed through use of a laser range finder. At the depth of highest concentration the dingy will then be maneuvered forward. If the concentration level rises, then the dingy will stop at the point of highest concentration and conduct a vertical profile. If the concentration falls, then the dingy will be swept forward until a reading of 8 ug/L is reached, and then a profile performed. This process is then repeated by maneuvering the dingy aft.
  - Subsequent sweeps are to be made at 35, 25, 20, 15, and 10 feet.
  - Visual reviews of wider dispersion will be made from the vessel bridge. These will be followed up with testing of concentrations of visual sites by the dingy.
- Environmental data will be gained by the setting of a current drogue by the dingy team before and after the discharge event. In addition, environmental data will gained from the vessel navigation suite and crew.

## PRESENTATION QUESTIONS AND ANSWERS:

The following summarizes additional information provided to answer questions posed. There were no questions which were left outstanding.

### Location determination

By tethering the dingy to the vessels hull with a line of definite length, a fixed radial distance from the overboard can be assured. This bridal system comes with the desired distances, 50, 35, 25, 20, 15, and 10 feet, as fixed points. This radial distance is then used as the hypotenuse of a right triangle.

The leg of this right triangle is completed with the use of a laser finder, accurate to less than an inch within 50 feet of the vessel hull. A feature of the instrument is storing the shortest distance recorded, as the user sweeps the hull first horizontally and then vertically. This leg completes the data needed to triangulate position.

GPS location devices were considered. Shadows from the vessel hull, interfering with satellite reception, as well as error of signal were understood. Relative positioning systems were considered to correct errors, and will be considered as viable options for future testing. However, the triangulation system noted above was selected as simpler and more appropriate for this specific test.

**Dingy wake**

The dingy is outfitted with a small outboard engine for maneuvering and tethering to the vessel. Once the dingy is attached to the vessel, oars will be used to maintain the tether line taut, and move forward and aft. In this way the impact of the small dingy on the plume can be minimized. In addition, the sampling pattern will start from the outside and move closer in. This method has already been tested and verified on the subject vessel.

**Further testing**

There have been extensive dispersion studies conducted to date. Included in this body of information are studies involving discharges from vessels. There are also computer models available for the prediction of fluid behaviors in way of dispersion. Why then, is it necessary to conduct full scale testing?

Glosten has conducted a limited literature search which identified a need for data specific to the variables section of this report. In addition, need for data close to the vessel hull is not supported by the hydrological studies and models available.

It should be noted that this test will define the plume characteristics for this specific vessel under specific conditions. It may be possible to make predictions on how limited changes in these variables will affect the plume. It may also be possible to translate these predictions to different vessels.

The results of this testing set should serve the near term need of defining dilution effects of the vessel targeted for testing of a biocide treated ballast water. However, it is hoped that by entering this data into the public domain, further work will be performed to support the greater need to understand ballast discharges from merchant vessels. This work could include:

- A literature search yielding how variation in the baseline variables tested will affect the dispersion plume. This can result in a creation of an appropriate model.
- Generation of a computation fluid dynamic model based on the baseline variables, can provide a useful tool for more accurately studying the interaction between variables.
- Model testing can be set-up to study variation of the variables in a controlled environment. Coupled with the full-scale test, further plume behavior predictions can be made.
- Additional full scale testing on the same vessel, and other vessels, can verify model predictions.